Sources:

Science Abstracts, Section A: Physics Abstracts, 1957 through February, 1963

Three or four abstracts were picked up in Chemical Abstracts, 1962 which did not appear in the Physics Abstracts.

Arrangement:

According to Physics Abstracts headings:

Gravitation. Relativity
Solid State Physics
Lattice Mechanics
Elementary Particles - Nucleus
Magnetic Properties of Solids

and then alphabetically by author.

530.12 : 539.12 : 539.14

10570 APPARENT WEIGHT OF PHOTONS.
R.V.Pound and G.A.Rebka, Jr.
Phys. Rev. Letters, Vol. 4, No. 7, 337-41 (April 1, 1960).

When emitted without nuclear recoil, the 14.4 keV γ-ray from the 0.1 μsec first excited state of Fe^{57} provides a very well defined frequency, the line having a fractional full width at half height of 1.13×10^{-12} for a carefully prepared source. This radiation has been used to detect the gravitational red-shift by measurement of the apparent shift of frequency between photons travelling vertically downwards through a height of 74 ft and being resonantly absorbed in a Fe^{57} foil, and photons travelling vertically upwards through the same height. The shift was measured by determining the difference in transmission of the absorber when the source was travelling towards and away from it with equal velocities. The source was oscillated using a ferroelectric or moving-coil transducer. Another absorber 3 ft from the source monitored the stability of the equipment. Corrections to the results were required for two effects: (a) A frequency shift due to temperature differences between source and absorber produced by second-order Doppler effect. A temperature difference of 1°C would produce a shift comparable with the gravitational effect. (b) A frequency shift characteristic of the combination of the source with any particular absorber. This could be accounted for also by second-order Doppler effect and differences of up to 11% in the Debye temperature of the lattice. This effect varied considerably using different absorbers and was at most ~5 times greater than the gravitational effect. After correction, the data yielded a net fractional shift $\delta\nu/\nu = -(5.13 \pm 0.51) \times 10^{-15}$ between the rising and falling photons compared with a theoretical prediction of -4.92×10^{-15}.
R.E.Meads

10569 SEARCH FOR THE ANISOTROPY OF INERTIA USING THE MÖSSBAUER EFFECT IN Fe^{57}.
C.W.Sherwin, H.Frauenfelder, E.L.Garwin, E.Lüscher, S.Margulies and R.N.Peacock.
Phys. Rev. Letters, Vol. 4, No. 8, 399-401 (April 15, 1960).

A description is given of unsuccessful attempts to detect a broadening of the central resonance absorption line of Fe^{57} due to the local asymmetric distribution of matter. An upper limit of 10^{-15} is found for the relative energy shift, $\Delta E/E$, which, making tentative assumptions, implies that the relative local anisotropy of inertia, $\Delta M/M$, is less than 5×10^{-16}.
E.A.Sanderson

530.12 : 539.14

18918 FIRST-ORDER TERRESTRIAL ETHER DRIFT EXPERIMENT USING THE MÖSSBAUER RADIATION.
M.Ruderfer.
Phys. Rev. Letters, Vol. 5, No. 5, 191-2 (Sept. 1, 1960).

Radiation travelling from the centre to the periphery of a revolving turntable moving through the aether would fluctuate in frequency. The author estimates that at 1800 r p.m., with path length 0.1 m, and "least count" sensitivity 3 parts in 10^{14} for the Mössbauer radiation, an aether drift of 1.5 m sec^{-1} should be detectable.
F.A.E.Pirani

1055 FIRST-ORDER TERRESTRIAL ETHER DRIFT USING THE MÖSSBAUER RADIATION. M.Ruderfer.
Phys. Rev. Letters (USA), Vol. 7, No. 9, 361 (Nov. 1, 1961).

The theory of the proposed experiment (Abstr. 18918 of 1960) is incomplete because even the Fitzgerald—Lorentz contraction theory predicts first-order changes of frequency with velocity, and so a null result (as with special relativity).
C.W.Kilmister

530.12 : 539.14

18917 SOME RECENT EXPERIMENTAL TESTS OF THE "CLOCK PARADOX". C.W.Sherwin.
Phys. Rev., Vol. 120, No. 1, 17-21 (Oct. 1, 1960).

Recent experiments by Pound and Rebka on the temperature dependence of the Mössbauer effect in Fe^{57}, and by Hay, Schiffer, Cranshaw, and Egelstaff using an Fe^{57} absorber on a rotating drum, are shown to provide the first direct experimental verification of the time-keeping properties of accelerated clocks such as occur in the classic "clock paradox" of relativity. In the experiment by Pound and Rebka, the thermal vibrations of the lattice impart r.m.s. velocities of about $10^{-6}c$, and nearly continuous, randomly-oriented accelerations of the order of $10^{16}g$ to both the source and the absorber nuclei. In the experiment by Hay et al. the acceleration of the absorber was $6 \times 10^{4}g$. The photon provides continuous communication of time data between the two nuclei for the duration of the "journey" (the emission time of the quantum). In each case the observed fractional frequency shift $\Delta f/f_0$ which occurs between the source and the absorber is found to be $-v_S^2/2c^2 + v_a^2/2c^2$, where v_S and v_a are the r.m.s. velocities of the source and the absorber nuclei, respectively. These results are in quantitative agreement with the generally accepted calculations for the "clock paradox", in which two clocks pursue independent paths (at least one of which involves accelerations) in a common inertial frame, but are compared at two or more points where they coincide in space and time. The temperature-dependent experiments also demonstrate that accelerations of the order of $10^{16}g$, arising from lattice vibrations, produce no intrinsic frequency shift in Fe^{57} nuclei to an accuracy exceeding 1 part in 10^{13}.

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14357 MÖSSBAUER EFFECT IN $Sm_2^{149}O_3$.
V.P.Alfimenkov, Yu.M.Ostanevich, T.Ruskov,
A.V.Strelkov, F.L.Shapiro and Yai' U-Guan [Yen Wu-kuang].
Zh. eksper. teor. Fiz. (USSR), Vol. 42, No. 4, 1036-7 (April, 1962).
In Russian.

The Mössbauer effect is observed for the 22 keV line from the Sm^{149} nucleus. This proves that the 22 keV transition proceeds to the ground state of Sm^{149}. The upper limit of the natural level width is determined, $\Gamma \le 6 \times 10^{-7}$ eV. [English translation in: Soviet Physics—JETP (USA)].

THE MÖSSBAUER EFFECT.
18512 A.J.F.Boyle and H.E.Hall.
Rep. Progr. Phys. (GB), Vol. 25, 442-515 (1962).

The recoilless emission and resonant absorption of low energy γ-rays by solids (Mössbauer effect) is reviewed, with particular reference to the present and future applications to solid state and nuclear physics.

INVESTIGATION OF THE MÖSSBAUER EFFECT IN A
10930 TIN-CONTAINING POLYMER.
V.A.Bryukhanov, V.I.Gol'danskii, N.N.Delyagin, E.F.Makarov and V.S.Shpinel'.
Zh. eksper. teor. Fiz. (USSR), Vol. 42, No. 2, 637-9 (Feb., 1962).
In Russian.

The Mössbauer resonance absorption of Sn^{119} in a tin-containing methylmethacrylate polymer was investigated. The polymer contained 30% by weight of tin and measurements were made at temperatures of 77°, 195° and 300°K. At 77°K a 10% effect was observed and the velocity spectrum showed two transmission dips with a separation of 3 mm sec. This suggests either a quadrupole effect or the existence of two different types of tin site in the polymer. The effect falls off less rapidly with temperature than predicted by a Debye model. [English translation in: Soviet Physics—JETP (USA)].
D.A.O'Connor

744 PECULIARITIES OF MÖSSBAUER SPECTRA OF TIN-ORGANIC COMPOUNDS AND THE ROLE OF THE NEAREST CHEMICAL BONDS IN THE MÖSSBAUER EFFECT.
V.A.Bryukhanov, V.I.Gol'danskii, N.N.Delyagin, L.A.Korytko, E.F.Makarov, I.P.Suzdalev and V.S.Shpinel', In Russian.
Zh. eksper. teor. Fiz. (USSR), Vol. 43, No. 2(8), 448-52 (Aug., 1962).
English translation in: Soviet Physics—JETP (USA).

It was found in investigating the Mössbauer effect in tin-organic compounds that singlet Mössbauer lines appear in compounds with four identical substituents ($SnCl_4$, Sn ($C_6H_5)_4$) whereas if different substituents ($R_i Sn X_{4-i}$) are present in the molecule a very strong doublet splitting of the Mössbauer lines occurs (the two peaks sometimes being different in intensity and width). The Mössbauer effect was observed in amorphous media (tin-containing glass) for the first time. Some data were obtained which indicate that the decisive factor determining the shapes of the Mössbauer spectra (isomer shift and quadrupole splitting) are the molecular bonds closest to the tin nuclei.

2043 THE ANISOTROPY OF THE MÖSSBAUER EFFECT.
Yu.Kagan.
Dokl. Akad. Nauk SSSR, Vol. 140, No. 4, 794-6 (Oct. 1, 1961).
In Russian.

The magnitude of this effect is estimated for a simple lattice of a rhombic system, in which atoms interact with nearest neighbours. Results are calculated for white tin. Direct calculations show that the anisotropic effect changes little with increasing temperature. [English translation in: Soviet Physics—Doklady (USA)].
E.A.Sanderson

10309 Yu.Kagan.
Dokl. Akad. Nauk SSSR, Vol.140, No. 4, 794-6 (Oct. 1, 1961).
In Russian. English translation in: Soviet Physics—Doklady (USA).
Vol. 6, No. 10, 881-2 (April, 1962).
For abstract see Abstr. 2043 of 1962.

12367 INFORMATION ON THE HYPERFINE STRUCTURE SPLITTING OF THE 8.42 keV γ-RAY OF Tm^{169} FROM THE MÖSSBAUER EFFECT IN Tm_2O_3. M.Kalvius.
Z. Naturforsch. (Germany), Vol. 17a, No. 3, 248-59 (March, 1962).
In German.

The recoilless nuclear resonance absorption of the 8.42 keV γ-ray of Tm^{169} in the oxide crystal was investigated. The source (Er_2O_3) and the absorber (Tm_2O_3) were kept at room temperature. The measured Mössbauer spectrum indicates pure quadrupole splitting of the 8.42 keV nuclear level of Tm^{169} for the thulium ions with C_2-symmetry as well as for those with C_{3i}-symmetry. The energy of the electric interaction was found to be $W_{el}(C_2) = 8 \times 10^{-7}$ eV and $W_{el}(C_{3i}) = 1.9 \times 10^{-8}$ eV.

10303 MEASUREMENTS OF THE Fe^{57} MÖSSBAUER EFFECT IN NUMEROUS IRON COMPOUNDS AT VARIOUS TEMPERATURES. W.Kerler and W.Neuwirth.
Z. Phys. (Germany), Vol. 167, No. 2, 176-93 (1962). In German.

A systematic investigation of iron compounds was performed using the Mössbauer effect. The velocity recording system was similar to that used by Sunyar (Abstr. 10961 of 1961), containing, however, a different type of velocity-to-pulse-height convertor, an 600 ohm loudspeaker, a highly-stabilized wideband d.c. amplifier, and only one γ-ray detector. A source of Co^{57}, diffused in Pt, with about the natural linewidth an low background was used. Precise data of shifts, splittings, widths, and intensities of the absorption lines are given for various compounds at different temperatures. The line shift was detected for small temperature differences. A small quadrupole splitting was measured for some trivalent iron salts. Our data confirm the grouping of the shifts of trivalent and divalent iron compounds and allow the possibility of further discussions of line shifts, quadrupole splittings, Debye—Waller factors, and the temperature dependence of these quantities. In addition, a comparison between scattering experiments and transmission experiments has been made, and resonance was also found with sources of Co salts.

10304 INVESTIGATION OF CRYSTAL PROPERTIES USING THE Fe^{57} MÖSSBAUER EFFECT. W.Kerler.
Z. Phys. (Germany), Vol. 167, No. 2, 194-204 (1962). In German.

A further evaluation and discussion of data obtained (see preceding abstract) on the Mössbauer effect in iron compounds was carried out. In addition to confirmation of the grouping line shifts for trivalent and for divalent iron compounds suggestions for an explanation of the behaviour of complex salts are made. The temperature dependence of the shift, which had only been known for Fe metal, is shown to be linear in the range of measurement for all substances investigated, with an astonishing small slope for the complex salts. The quadrupole splitting and its temperature dependence is discussed for the different types of chemical bonds involved. After elimination of the dependences on absorber thickness and temperature from the measured linewidths, it was shown that the source of Co^{57} in Pt has about the natural linewidth and that there is a line broadening in most absorbers, increasing with chemical instability. Using the temperature dependence, an accurate determination of Debye—Waller factors is possible. These factors show a grouping for salts and for metals respectively.

10301 VELOCITY SHIFT OF THE MÖSSBAUER RESONANCE.
A.A.Maradudin, P.A.Flinn and S.Ruby.
Phys. Rev. (USA), Vol. 126, No. 1, 9-23 (April 1, 1962).

The mean square velocity of an impurity atom in a crystal lattice was evaluated in both the low and high temperature limits. The result for the high temperature limit includes the effect of force constant differences between solute and solvent atoms as well as the effect of mass difference. The effect of a mass difference alone is quite small in both the low temperature and high temperature regions. A determination of the Mössbauer peak position as a function of temperature in the high temperature range can be used to obtain a value of isomeric shift fully correct for the second order Doppler shift associated with the vibration of the atoms. In addition, if the experimental data are sufficiently precise, the effective stiffness with which the atoms are bound in the lattice may be determined. The calculation is illustrated with experimental data for Fe^{57} dissolved in beryllium and in stainless steel.

2

9999 ON THE THEORY OF THE MÖSSBAUER EFFECT.
F.Sauter and D.Wagner.
Z. Naturforsch. (Germany), Vol. 17, No. 1, 30-6 (Jan., 1962).
In German.

It is shown that an understanding of the Mössbauer effect is possible from the point of view of classical physics. Quantum theory is taken into account in the manner usual in optical problems. The main point of this semiclassical interpretation consists in the idea that the recoil momentum given to the emitting nucleus in the lifetime τ of the γ-ray is dissipated during this time by the lattice vibrations so that the Doppler shift is unobservable. An analysis of the continuum part of the spectrum follows in analogy with von Laue's treatment of X-ray scattering from a crystal at a finite temperature.   B.V.Thompson

20907 MÖSSBAUER EFFECT ISOMER SHIFT OF Fe^{57} IN SILICON AND GERMANIUM.
P.C.Norem and G.K.Wertheim.
J. Phys. Chem. Solids (GB), Vol. 23, 1111-18 (Aug., 1962).

The Mössbauer spectra of Fe^{57} in n- and p-type silicon and germanium were studied. In silicon, iron produced by the decay of cobalt has a dominant, unsplit absorption at -0.0012 ± 0.0003 cm sec doppler velocity relative to potassium ferrocyanide. No difference in isomer shift was observed between n- and p-type silicon, indicating that the iron tested was electrically inactive. The spectrum of substitutional Fe^{57} was identified with an absorption at +0.054 ± 0.004 cm sec showing less than 3 Mc s electric quadrupole splitting. The spectrum of iron produced by the decay of cobalt in germanium is a doublet with an isomer shift of +0.036 ± 0.001 cm sec and with a quadrupole splitting of 5 Mc s. It is assumed that this splitting is due to the asymmetrical positions of the Fe^2 and Fe^{1-} atoms in the germanium lattice. No differences in isomer shift or quadrupole splitting were observed between iron in n- and p-type germanium, indicating that the iron is electrically inactive.

3471 LINE SHAPE IN MÖSSBAUER SPECTROSCOPY.
S.L.Ruby and J.M.Hicks.
Rev. sci. Instrum. (USA), Vol. 33, No. 1, 27-30 (Jan., 1962).

The line shape, amplitude and half-width to be expected from a natural linewidth thin source and a natural linewidth Mössbauer absorber was computed as a function of the thickness of the absorber. The experimental result, using stainless steel source and absorber and correcting for background, has double the expected width, but nearly the correct fractional change in rate. This is compatible with a blurring due to dissimilar micro-environments of about ±0.10 mm sec.

2042 THEORETICAL CONSIDERATIONS ON THE MÖSSBAUER EFFECT. J.van Kranendonk.
Ned. Tijdschrift Natuurkde (Netherlands), Vol. 27, No. 7, 251-68 (July, 1961). In Dutch.

The article, which is based on a contribution to the session on the Mössbauer effect at the Low Temperature Conference in Toronto in 1960, sets out the fundamentals of the effect. The principle of "recoilless" transitions is discussed in some detail, the quantum and classical theories of the Mössbauer effect are considered, and attention is given to frequency shifts and hyperfine structure of Mössbauer lines.   J.Thewlis

10300 MÖSSBAUER EFFECT IN SOME IRON--RARE EARTH INTERMETALLIC COMPOUNDS.
G.K.Wertheim and J.H.Wernick.
Phys. Rev. (USA), Vol. 125, No. 6, 1937-49 (March 15, 1962)

The magnetic properties of iron in cubic Laves-phase compounds having the $MgCu_2$ structure were investigated using the Fe^{57} Mössbauer effect. The field at the nucleus was found to be 230 ± 5 kOe in all compounds except $CeFe_2$ where two distinct hyperfine structures were resolved. The results indicate that the configuration of the iron atoms is the same in all these compounds and that the contribution to the hyperfine field by the conduction electron polarization is either very small or else dominated by the iron d shell. The more complex behaviour in $CeFe_2$ is associated with the transfer of the cerium 4f electron to the iron d band. The isomer shift indicates that this electron is not localized on a particular iron atom, while the existence of two distinct hyperfine fields suggests that there may be a spatially periodic spin density fluctuation in the d band.

20909 MÖSSBAUER EFFECT IN IRON (III) ACETYLACETONATE AND CHEMICAL CONSEQUENCES OF K CAPTURE IN COBALT (III) ACETYLACETONATE.
G.K.Wertheim, W.R.Kingston and R.H.Herber.
J. chem. Phys. (USA), Vol. 37, No. 4, 687-90 (Aug. 15, 1962).

The resonance absorption of 14.4 keV gamma-rays in Fe^{57} (Mössbauer effect) was observed in Fe(III) and Co(III) acetylacetonate, the former used as an absorber against a source of Co^{57} diffused into metallic chromium, the latter as a Co^{57} labelled source against a $K_4Fe(CN)_6$ (38_c Fe^{57}) absorber. The Fe(III) acetylacetonate absorber spectrum shows a single broad line ($\Gamma_{1,2}$ = 1.83 ± 0.09 mm sec^{-1}) with an isomer shift of 0.50 ± 0.09 mm sec^{-1}. The Co(III) acetylacetonate source shows a complex spectrum which can be resolved into a single peak assigned to Fe(III) and a quadrupole split pair of lines assigned to Fe(II). These data are interpreted in terms of the chemical consequences following K capture in Co^{57}, and suggest a twofold preference for the stabilization of the higher charge state in the Co (III) acetylacetonate matrix. No evidence for ionic charge states higher than 3+ is observed, and it is assumed that these species — if formed as a consequence of the prior nuclear event — have been reduced to the observed states in times short compared to 10^{-7} sec.

3817 MÖSSBAUER EFFECT IN Sn^{119} IN NORMALLY AND SUPERCONDUCTING CONDITION.
W.H.Wiedemann, P.Kienle and F.Pobell.
Z. Phys. (Germany), Vol. 166, No. 1, 109-14 (1962). In German.

The number of Mössbauer quanta from the 23.8 keV state of Sn^{119} in a tin metal source was measured after attenuation by a 16.1 mg cm^2 absorber of tin metal as a function of temperature above and below the superconducting transition point. Source and absorber were kept at the same temperature. The data give evidence of a discontinuous change at the transition temperature: The transmitted intensity is lowered by (1.3 ± 0.15) $\times$ 10^{-3} in the superconducting state of source and absorber. This corresponds to an increase in the Debye-Waller factor of about 0.4%.

3604 THE MÖSSBAUER EFFECT IN TIN FROM 120°K TO THE MELTING POINT.

A.J.F.Boyle, D.S.P.Bunbury, C.Edwards and H.E.Hall.

Proc. Phys. Soc. (GB), Vol. 77, Pt 1, 129-35 (Jan., 1961).

Measurements were made of the intensity of the recoilless resonance absorption of the 24 keV γ-ray from the decay of Sn^{119m} in metallic tin from 120°K to the melting point. Values of the Debye—Waller factor deduced from the data tend towards the values calculated for a Debye Θ of 142°K at low temperatures; the behaviour of the Debye—Waller factor at higher temperatures indicates considerable anharmonicity of the lattice vibrations. Comparison with evidence from the thermal expansion and specific heat suggests that the quartic term in the interatomic potential is positive, and that the ratio of quartic to cubic terms is of the same order as the ratio of cubic to quadratic terms. In the last few degrees below the melting point the resonance absorption shows a rapid drop accompanied by an increase in line width. It is suggested that this effect is due to enhanced self-diffusion in the solid, and it is estimated that the diffusion coefficient reaches a value of 10^{-8} cm^2 sec^{-1} about 0.6°K below the melting point.

539.14

13128 ZEEMAN EFFECT IN THE RECOILLESS γ-RAY RESONANCE OF Zn^{67}.

P.P.Craig, D.E.Nagle and D.R.F.Cochran.

Phys. Rev. Letters, Vol. 4, No. 11, 561-4 (June 1, 1960).

A detailed description is given of measurements carried out on the influence of the nuclear Zeeman effect and other perturbations upon the Mössbauer effect in Zn^{67} embedded in an enriched ZnO lattice. A tentative discussion is made of the factors which possibly contribute to the features of the resonance curve obtained.

E.A.Sanderson

19693 MÖSSBAUER EFFECT MEASUREMENTS ON SUPER-CONDUCTING INDIUM.

P.P.Craig, R.D.Taylor and D.E.Nagle.

Nuovo Cimento (Italy), Vol. 22, No. 2, 402-5 (Oct. 16, 1961).

The amplitude and width of the Mössbauer resonance in Fe^{57} was measured for Fe^{57} as a very dilute impurity in metallic In. The resonance amplitude is found to remain substantially unchanged in the temperature interval 0.35°-4°K, showing that the Debye temperature of In increases by less than 3 deg K in this temperature range. Specific heat measurements on In had indicated a possible Debye temperature change of 12 deg K. As the source is cooled from 300° to 4°K the resonance amplitude increases by only 50% in contrast to the minimum of 500% calculated from the Debye—Waller factor.

539.2

20788 THE HYPERFINE STRUCTURE OF γ-RAYS, DUE TO THE QUADRUPOLE INTERACTION IN A CRYSTAL LATTICE. N.N.Delyagin, V.S.Shpinel', V.A.Bryukhanov and B.Zvenglinskii.

Zh. eksper. teor. Fiz., Vol. 39, No. 1(7), 220-2 (July, 1960). In Russian.

The hyperfine structure of the 23.8 keV excited state of Sn^{119} was investigated, by means of a Mössbauer-type experiment in which the velocity of the source changed linearly with time. The distance between the components of the hyperfine structure was found to be $(1.15 \pm 0.25) \times 10^{-7}$ eV, but lack of knowledge of the electric field gradient in crystalline tin prevented the determination of the quadrupole moment of the excited state. E.A.Sanderson

19694 PRESSURE DEPENDENCE OF THE MÖSSBAUER EFFECT. R.V.Hanks.

Phys. Rev. (USA), Vol. 124, No. 5, 1319-20 (Dec. 1, 1961).

The pressure dependence is examined and expressions are given (in the Debye approximation) for the probability of recoilless emission (absorption) as a function of the specific volume. It is concluded that the effect of pressure is slight for metals such as Zn, Sn, etc., but that more compressible elements should exhibit observable pressure dependences at moderate pressures. A calculation is given which predicts that the recoilless emission of the 81 keV line in Cs^{133} should become observable at a pressure of about 5000 atm. Some additional experiments involving the above pressure dependence are also discussed.

19695 ON THE PARTICULAR ROLE OF THE OPTICAL BRANCH IN THE MÖSSBAUER EFFECT. Yu.Kagan.

Zh. eksper. teor. Fiz. (USSR), Vol. 41, No. 2(8), 659-61 (Aug., 1961). In Russian.

It is shown that analysis of the influence of the optical branch of the phonon spectrum in crystals on the magnitude of the Mössbauer effect may explain the anomalous temperature dependence of the effect recently observed in SnO_2 and Dy_2O_3, in which the size of the effect falls much more slowly with rising temperature than anticipated. [English translation in: Soviet Physics—JETP (USA)].

G.E.Murphy

556 THE MÖSSBAUER EFFECT IN MONO- AND DIATOMIC CUBIC LATTICES. Yu.Kagan and V.A.Maslov.

Zh. eksper. teor. Fiz. (USSR), Vol. 41, No. 4(10), 1296-1303 (Oct., 1961). In Russian.

Monatomic and diatomic cubic crystals are considered and central as well as non-central types of interaction with the nearest neighbour is taken into account. Derives an expression for probability of the Mössbauer effect at $T = 0$ as well as at an arbitrary temperature. The case of a diatomic lattice, when one of the atoms is an emitter, is analysed. It is shown, in particular, that for a light emitter in a diatomic lattice, the effect may be larger than that in a monoatomic lattice with the same Debye temperature. It is found that, in the general case, the Debye temperature for a diatomic lattice does not even approximately characterize the probability of the Mössbauer effect. [English translation in: Soviet Physics—JETP (USA)].

8156 THE MÖSSBAUER EFFECT FOR AN IMPURITY NUCLEUS IN A CRYSTAL.

Yu.Kagan and Ya.A.Iosilevskii.

Zh. eksper. teor. Fiz. (USSR), Vol. 42, No. 1, 259-72 (Jan., 1962). In Russian.

The probability of the Mössbauer effect is determined for an impurity nucleus at the lattice point of a crystal. The change in the mass and also force constants due to the impurity lattice point are taken into account. The role of a discrete and quasi-continuous phonon spectra is analysed. The case of a cubic crystal is considered in detail. The final formulae depend on the properties of the basic lattice only by means of the distribution function of the phonon frequency spectrum. Explicit expressions are given for the probability of the effect in the limiting cases, when the mass of the impurity atoms is small or large as compared to the mass of the basic lattice atoms. [English translation in: Soviet Physics—JETP (USA)].

4

11561 EVIDENCE FOR QUADRUPOLE INTERACTION OF Fe^{57*}, AND INFLUENCE OF CHEMICAL BINDING ON NUCLEAR GAMMA-RAY ENERGY. O.C.Kistner and A.W.Sunyar

Phys. Rev. Letters, Vol. 4, No. 8, 412-15 (April 15, 1960).

The Mössbauer effect is used to determine the quadrupole coupling for the $\frac{3}{2}$-excited state and the energy shift of the 14.4 keV nuclear gamma-ray of Fe^{57} bound in Fe$_2$O$_3$. In order to fit the observed data an energy shift $\Delta E = (2.26 \pm 0.15) \times 10^{-8}$ eV is required between the centre of gravity of the absorption lines of Fe^{57} in Fe$_2$O$_3$ and the emission line of Fe^{57} bound in stainless steel. Further necessary shifts, $\epsilon = \pm 5.75 \times 10^{-9}$ eV (+ve for $|m| = \frac{1}{2}$, -ve for $|m| = \frac{3}{2}$), in the individual hyperfine levels of the excited state are attributed to quadrupole interaction The measurements give values of 0.611 ± 0.005 cm/sec and 0.345 ± 0.003 cm. sec. respectively, for the splitting parameters of the ground and excited states of Fe^{57} in Fe$_2$O$_3$ and the internal magnetic field in antiferro-magnetic Fe$_2$O$_3$ is found to be 1.547 ± 0.022 times as large as that in ferromagnetic iron. The relative intensities of the absorption lines confirm the inverted hyperfine pattern for the $\frac{3}{2}$ state. Possible reasons for the energy shift ΔE due to chemical environment effects are discussed.   E.A.Sanderson

19696 WIDTH AND SHAPE OF MÖSSBAUER LINES IN SOLID SOLUTIONS. M.A.Krivoglaz.

Zh. eksper. teor. Fiz. (USSR), Vol. 41, No. 3(9), 765-72 (Sept., 1961). In Russian.

The Mössbauer effect in solid solutions is studied. The dependence of vibrational energy due to variation of the mass of the absorbing or radiating nucleus on the configuration of various types of atoms surrounding the nucleus is taken into account explicitly. Mössbauer line broadening due to this cause is estimated and the line shape in solid solutions is considered for the extreme cases of a large and small natural width. Other causes of Mössbauer line broadening in solid solutions are indicated. [English translation in: Soviet Physics—JETP (USA)].

23046 WIDTH AND SHAPE OF MOSSBAUER LINES IN SOLID SOLUTIONS. M.A.Krivoglaz.

Zh. eksper. teor. Fiz. (USSR), Vol. 41, No. 3(9), 765-72 (Sept.,1961). In Russian. English translation in: Soviet Physics—JETP (USA), Vol. 14, No. 3, 552-6 (March, 1962).

For abstract see Abstr. 19696 of 1961.

11146 DEBYE—WALLER FACTOR IN MÖSSBAUER INTER-FERENCE EXPERIMENTS. H.J.Lipkin.

Phys. Rev. (USA), Vol. 123, No. 1, 62-3 (July 1, 1961).

A simple calculation is presented of the effects of lattice dynamics on interference between Mössbauer processes and corres-ponding atomic processes, i.e., between Mössbauer and Rayleigh scattering, or between internal conversion of Mössbauer radiation and the photoelectric effect. When the energy of the emitted γ-ray or electron is not measured, it is necessary to sum over all possible final states of the lattice. The interference contribution is found to be attenuated by the same "Debye—Waller" factor as the ordinary Mössbauer contribution, depending only upon the momentum of the incident γ-ray. If the energy of the emitted γ-ray is measured (e.g., by a Bragg scattering experiment), the atomic contribution is attenuated by the usual X-ray Debye—Waller factor, depending upon the momentum transfer, the Mössbauer contribution by the square of the usual Mössbauer factor, and the interference term by the geometric mean of the atomic and Mössbauer factors.

14364 SOME SIMPLE FEATURES OF THE MÖSSBAUER EFFECT. II. SUM RULES AND THE MOMENTS OF THE ENERGY SPECTRUM. H.J.Lipkin.

Ann. Phys. (USA), Vol. 18, No. 2, 182-97 (May, 1962).

For Pt I. see Abstr. 7461 of 1960. General expressions for the moments of the Mössbauer energy spectrum are derived and sum rules for the second moment (dispersion), as well as for the first, are calculated. By examining these results one obtains physical insight into the mechanism of the momentum transfer to the lattice and appreciates the importance of the quantum-mechanical zero-point motion which cannot produce a Doppler shift in the classical sense. The principal effect of the binding forces is not to "hold the atom in the crystal" during the emission of the gamma ray; rather it is to produce zero-point motion before the emission. The well known expression for the "Mössbauer fraction" in a crystal is derived in a simple way using the sum rule for the second moment.

20789 USE OF THE MÖSSBAUER EFFECT FOR THE INVESTI-GATION OF LOCALIZED ATOMIC OSCILLATIONS IN SOLIDS. S.V.Maleev.

Zh. eksper. teor. Fiz., Vol. 39, No. 3(9), 891-2 (Sept., 1960). In Russian.

Discusses the possibility of observing and investigating atomic-oscillation peaks due to the emission and absorption of quanta of localized oscillations.   E.A.Sanderson

14366 DEBYE—WALLER FACTOR FOR MÖSSBAUER RESONANT IMPURITY ATOMS.

A.A.Maradudin and P.A.Flinn.

Phys. Rev. (USA), Vol. 126, No. 6, 2059-71 (June 15, 1962).

The probability for recoilless resonant gamma-ray emission or absorption by atoms present as impurities in a host lattice was evaluated in the high-temperature limit. The effect of interatomic force constant differences between impurity atoms and host lattice atoms is included explicitly for a simple model. The first order quantum corrections have been calculated for the case of an isotopic impurity (no force constant difference). The Debye—Waller factor at high temperatures is determined largely by the stiffness of the host lattice, and partially by the forces between host and impurity atoms. The effects of the host and impurity masses appear only in the quantum corrections.

11134 DEVELOPMENTS IN GAMMA-RAY OPTICS. P.B.Moon.

Nature (London), Vol. 185, 427-9 (Feb. 13, 1960).

A short review of recent work on the spectroscopy, scattering and resonance processes of gamma-rays. Particular attention is given to the Mössbauer effect (Abstr. 9040 of 1958) in which emission occurs with recoil of the whole lattice instead of a single atom, so that the emission line is extraordinarily sharp. Some of the possible applications of this effect in research in both nuclear and solid state physics are suggested.   V.E.Cosslett

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2698. Mössbauer study of hyperfine solid, quadrupole interaction, and isomer shift in Fe^{57} in $FeS_{1.00}$, $FeS_{1.05}$ and $FeS_{1.07}$.
K. Ono, A. Ito and F. Hirahara. J. Phys. Soc. Japan, Vol.17, No. 10, 1615-20. (Oct., 1962)

The hyperfine structures of Fe^{57} in $FeS_{1.00}$, $FeS_{1.05}$ and $FeS_{1.07}$ were investigated by Mössbauer absorption. The extrapolated values of the magnetic fields at the iron nuclei in $FeS_{1.00}$, $FeS_{1.05}$ and $FeS_{1.07}$ are 328, 318 and 324 kOe at $0°K$ respectively. The energy shifts due to the quadrupole interaction in $FeS_{1.05}$ at $290°$ and $90°K$ have opposite sign and their ratio is -2.8. The corresponding ratio in $FeS_{1.07}$ is -2.0. This indicates that the antiferromagnetic easy axis changes by $90°$ through the transition temperature from the c axis, which is considered as the direction of the largest electric field gradient, onto the c plane, while direction and values of the electric field gradient remains unchanged. Observed internal magnetic fields quadrupole coupling constants, and isomer shifts at various temperatures are given.

11455 MAGNETIC ANOMALY IN $FeTiO_3-\alpha Fe_2O_3$ SYSTEM BY MÖSSBAUER EFFECT. S.L.Ruby and G.Shirane.
Phys. Rev. (USA). Vol. 123. No. 4. 1239-40 (Aug. 15, 1961).

The solid solutions $(1-x)FeTiO_3,-xFe_2O_3$, exhibit strong ferrimagnetic moments for the compositions x < 0.6, where the Fe and Ti ions are ordered in the alternate (111) layers. The anomaly revealed by the Mössbauer measurements is that the ferrimagnetic phase consists of ferrimagnetic clusters surrounded by paramagnetic media. The size of these clusters decreases with increasing temperature or increasing local concentration of Ti. The

isomer shift of $FeTiO_3$ is 1.2 mm/sec at room temperature as expected for Fe^{2+}, although the quadrupole splitting of 0.62 mm/sec is smaller than that observed in other ferrous environments.

10299 MÖSSBAUER STUDY OF HYPERFINE FIELDS AND ISOMER SHIFTS IN Fe_4N AND $(Fe,Ni)_4N$.
G.Shirane, W.J.Takei and S.L.Ruby.
Phys. Rev. (USA). Vol. 126. No. 1. 49-52 (April 1. 1962).

Mössbauer measurements of Fe^{57} were made on ferromagnetic Fe_4N, which has a face-centred cubic arrangement of iron atoms with nitrogen at the body-centre position. The hyperfine fields are 345 kOe for the corner Fe and 215 kOe for the three face-centre Fe, approximately proportional to their magnetic moments. 3 μ_B and 2 μ_B. The isomer shifts. measured against a stainless steel source, are 0.30 mm/sec for the corner Fe and 0.45 mm/sec for the face-centre Fe. These values are in line with their proposed electronic configurations of $3d^7 4s$ and $3d^9 4s$, which are derived on the assumption that the nitrogen at the body-centre position acts as an electron "donor" to the face-centre Fe. The Mössbauer spectra of $(Fe_{1-x}Ni_x)_4N$ and $(Fe,Ni)N$ are consistent with their ordered structures in which Ni replaces the corner Fe preferentially.

$CA 258 (1962)$

Moessbauer study of isomer shift. quadrupole interaction, and hyperfine field in several oxides containing Fe^{57}.
G. Shirane, D. E. Cox (Westinghouse Research Labs., Pittsburgh, Pa.). and S. L. Ruby. Phys. Rev. 125, 1158-65 (1962). Moessbauer absorption by Fe^{57} was used to study isomer shift, quadrupole splitting, and hyperfine fields in several oxides contg. Fe. The established relations between isomer shifts and ionic states of Fe were further confirmed by measurements on $Fe^{++}Ti_2O_3$. $Fe^{+++}TiO_3$ and several other mixed oxides. By utilizing this relation, in turn, to identify the ionic states when these are in doubt, it has been found that $(Fe,V)_2O_3$ incorporates the cation pair Fe^{+++}-V^{+++}, rather than $Fe^{++}-V^{4+}$, and that "$SrFeO_3$" contains Fe^{4+} and Fe^{+++} in the ratio of 3:1. A well-defined quadrupole splitting was observed in $Fe_{1-x}O$ and in a number of the solid solns. $(Fe,Mg)O$. although their overall symmetry is cubic. This is attributed to local asymmetry at the Fe nuclei caused either by vacancies or foreign ions. Hyperfine fields at the Fe^{+++} nuclei in $(Fe,Cr)_2O_3$. $(Fe,V)_2O_3$. and $(Fe,Al)_2O_3$ have values of 520-40 koe. when extrapolated to $0°K$., and the results are discussed in conjunction with their magnetic properties.   CA

20498 MÖSSBAUER EFFECT IN Eu^{151}; POSSIBLE INFLUENCE OF OPTICAL BRANCHES.
D.A.Shirley, M.Kaplan, R.W.Grant and D.A.Keller.
Phys. Rev. (USA), Vol. 127, No. 6, 2097-2100 (Sept. 15, 1962).

The Mössbauer effect was observed in the 21.7 keV transition in Eu^{151}. The absorption pattern is a single line, independent of temperature, as expected for an ion in which the ground level has J = 0. A lower limit of 0.92×10^{-8} sec can be set on the lifetime of the isomeric state. The 21.7 keV transition is, thus, about a factor of 100 slower than the single-particle estimate. The large discrepancy between the Debye temperatures required to fit the data of $77°$ and $295°K$ is attributed to the influence of optical branches.

8155 THE MÖSSBAUER EFFECT ON TUNGSTEN ISOTOPES
O.I.Sumbaev, A.I.Smirnov and V.S.Zykov.
Zh. eksper. teor. Fiz. (USSR), Vol. 42, No. 1, 115-23 (Jan., 1962).
In Russian.

The dependence of non-recoil nuclear resonance absorption of the 100.09 keV W^{182} and 99.07 keV and 46.48 keV W^{183} levels on the relative velocity between the source and absorber was investigated. The experimental arrangement was of such a type that the measurements could be carried out in the usual manner by separating the resonance line with the aid of a scintillation counter as well as by using for this purpose a focusing crystal diffraction γ-spectrometer of the Du Mond type with a resolving power of several tenths of a percent. The source (metallic tantalum) and absorber (metallic tungsten) Debye temperatures measured on the basis of the magnitude of the effect were found to be 280^{+30}_{-15} and 320^{+70}_{-45}°K respectively. Contrary to the conclusions of de Nercy et al. (Abstr. 7533 of 1960) the observed effect in all cases was not smaller than the theoretical value. The total widths of the indicated levels were measured. The width of the 100.09 keV level agrees with that derived by the Coulomb excitation method (Abstr. 9036 of 1958) and by delayed coincidences (Abstr. 5605 of 1955) but is not consistent with the result of a previous experiment on nuclear resonance absorption in W^{182} (Abstr. 412 of 1960). The experimental values of the widths are in good agreement with the theoretical values (Abstr. 4618 of 1957). [English translation in: Soviet Physics—JETP (USA)].

539.2 : 539.14

RECOILLESS RAYLEIGH SCATTERING IN SOLIDS.
11560 C.Tzara and R.Barloutaud.
Phys. Rev. Letters, Vol. 4, No. 8, 405-6 (April 15, 1960).

The Debye—Waller factor φ_T for the reduction in intensity of Bragg X-ray scattering by a solid at temperature T was determined for Pt, Al, graphite and paraffin by detecting the proportion of recoilless γ-rays using the Mössbauer effect. The Rayleigh scattering was studied at 80° and 300°K. The agreement between the experimental and calculated values of φ_T at 30°K is good.
E.A.Sanderson

23047 SURFACE EFFECTS IN THE SECOND-ORDER
DOPPLER SHIFT OF THE MÖSSBAUER RESONANCE.
R.F.Wallis and D.C.Gazis.
Phys. Rev. (USA), Vol. 128, No. 1, 106-10 (Oct. 1, 1962).

The second-order Doppler shift in the Mössbauer effect depends upon the mean-square velocities of the emitting and absorbing atoms. On the basis of a theorem discussed by Born in connection with the lattice dynamical theory of the Debye—Waller factor, a general expression is obtained for the mean-square velocity of an arbitrary atom in a crystal lattice, assuming harmonic forces. The result is valid for any temperature and may be applied to lattices having free surfaces or impurities. Approximate expressions are developed for the high- and low-temperature limits. The general results are applied to specific calculation of the mean-square velocity for atoms at or near a free surface. Ordinarily, the mean-square velocity turns out to be smaller for an atom at the surface than for one in the interior of the crystal. This is a consequence of the surface atom being linked to fewer neighbouring atoms than is the case for an interior atom. It is concluded, however, that whether or not a crystal lattice possesses surface modes of vibration has little direct bearing on the mean-square velocity of surface atoms.

539.14

20335 THE INFLUENCE OF ULTRASONICS ON THE EMISSION AND ABSORPTION OF γ-RAYS WITHOUT RECOIL.
A.Abragam.
C.R. Acad. Sci. (Paris), Vol. 250, No. 26, 4334-6 (June 27, 1960).
In French.

It is shown that the introduction of ultrasonics into a crystal containing γ-radioactive nuclei facilitates the frequency scanning of the Mössbauer spectrum.
E.A.Sanderson

539.14

9523 SOME POSSIBLE APPLICATIONS OF RESONANCE SCATTERING OF γ-RADIATION.
I.Ya.Barit, M.I.Podgoretskii and F.L.Shapiro.
Zh. eksper. teor. Fiz., Vol. 38, No. 1, 301-2 (Jan., 1960).
In Russian.

The Mossbauer effect (Abstr. 9040 of 1958; 1368 of 1960) in Ir^{191}, Zn^{67}, Ga^{67} is discussed as a possible tool for the measurement of Doppler, Zeeman and Einstein shifts.
J.W.Gardner

3469 METHOD OF MEASURING THE MÖSSBAUER EFFECT.
J.E.S.Bradley and J.Marks.
Nature (GB), Vol. 192, 1176-7 (Dec. 23, 1961).

A scintillation counter phosphor P was placed eccentrically inside a rotating drum D bearing the absorber and driven via a continuously variable gear, while the source S was mounted on a thick copper strip performing bending vibrations. The axis of rotation of D was below the line joining S to P so that the absorber had a known effective velocity relative to S. The signal was fed to a phase-sensitive detector the output of which is the first derivative of the Mössbauer line. This is shown for the 129 keV line of Ir^{191} obtained with an iridium foil absorber and a source strength of $60\,\mu c$. the time for the recording being ~ 1 hr.
I.C.Demetsopoullos

539.14 : 530.12

7470 UPPER LIMIT FOR THE ANISOTROPY OF INERTIA FROM THE MÖSSBAUER EFFECT.
G.Cocconi and E.E.Salpeter.
Phys. Rev. Letters, Vol. 4, No. 4, 176-7 (Feb. 15, 1960).

It is shown how the use of the Mössbauer effect enables an upper limit to be placed on the variation of inertial mass with direction of acceleration. Present results indicate that $\Delta M/M < \sim 10^{-11}$ but it should be possible to improve this limit considerably.
E.J.Squires

539.14

15518 WIDTH AND INTENSITY OF THE MÖSSBAUER LINE IN IRON-57. M.Cordey-Hayes, N.A.Dyson and P.B.Moon.
Proc. Phys. Soc., Vol. 75, Pt 5, 810-12 (May 1, 1960).

Sources of Co^{57} have been prepared by beating and rolling a fragment of a cyclotron target containing 2.2% Fe^{57} to a thickness of $20\,mg\,cm^{-2}$ and also by coprecipitation of Co^{57} and Fe^{57} hydroxides followed by reduction to the metal. These sources, together with a 24.7 $mg\,cm^{-2}$ absorber were used to determine the width and intensity of the Mössbauer resonant absorption line for the 14.4 keV γ-radiation of Fe^{57}. The ratio of the counting rates with the source moving to those with source stationary was plotted for different source velocities and the results indicate that the sources were emitting lines of natural width. Using another, isotopically enriched, absorber, the experiments yielded a value for the fraction of radiation emitted in the narrow line and hence the Debye-Waller factor for the source. This was $\sim 60\%$ compared with an expected value of 72% assuming a Debye temperature of $355°K$ for iron. Also, a value of $1.4 \times 10^{-19}cm^2$ was obtained for the initial cross-section for resonance absorption. This result is fairly consistent with full splitting in the internal magnetic field, the levels concerned in the transition.
R.E.Meads

539.14 : 530.12

7468 MEASUREMENT OF THE GRAVITATIONAL RED SHIFT USING THE MÖSSBAUER EFFECT IN Fe^{57}.
T.E.Cranshaw, J.P.Schiffer and A.B.Whitehead.
Phys. Rev. Letters, Vol. 4, No. 4, 163-4 (Feb. 15, 1960).

The experimental arrangement is described. The difference in height was 12.5 metres, which gives an expected fractional red shift of 1.36×10^{-15}. The observed shift was equal to the expected shift multiplied by 0.96 ± 0.45
E.J.Squires

539.14

7467 EXPERIMENTS TO TEST EINSTEIN'S PRINCIPLE OF EQUIVALENCE. T.E.Cranshaw and J.P.Schiffer.
Nature (London), Vol. 185, 653-4 (March 5, 1960).

Describes experiments utilizing the Mössbauer effect carried out independently at Harvard and at Harwell on measurement of the frequency shift due to the difference of the gravitational potential between an Fe^{57} emitter and an absorber placed at different heights. In another type of experiment, at Harwell, a rotating system was used giving accelerations of up to 65 000 g. The preliminary results are of the right magnitude.
W.A.Hepner

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17459 MÖSSBAUER EFFECT IN Fe^{57} AT VERY LOW TEMPERATURES. J.G.Dash, R.D.Taylor, P.P.Craig, D.E.Nagle, D.R.F.Cochran and W.E.Keller.
Phys. Rev. Letters, Vol. 5, No. 4, 152-4 (Aug. 15, 1960).

The effect on the intensity of the Mössbauer absorption pattern of a temperature difference between source and absorber was investigated. The results showed qualitative agreement with theory and demonstrated that the hyperfine field in Co^{57} is parallel to that in Fe, i.e., opposite to the ferromagnetic domain magnetization.
E.A.Sanderson

3389 CONTRIBUTION TO THE THEORY OF THE MÖSSBAUER EFFECT. I.P.Dzyub and A.F.Lubchenko.
Dokl. Akad. Nauk SSSR, Vol. 136, No. 1, 66-9 (Jan. 1, 1961).
In Russian.

Studies the criteria determining the shape of the intensity curve and the presence in the spectrum of unshifted lines, taking into account the dependence, upon the nuclear state, of the equilibrium positions and the normal frequencies of the lattice. The temperature shift of the Mossbauer line is determined. Maxima corresponding to emission and absorption are separated by a distance greater than the nuclear recoil energy from the Mossbauer line, the intensity of which is also decreased due to the effects of the displacements of the nuclei. [English translation in: Soviet Physics—Doklady (USA)].
E.A.Sanderson

539.14

5663 OBSERVATIONS ON THE MÖSSBAUER EFFECT IN Fe^{57}.
S.S.Hanna, J. Heberle, C.Littlejohn, G.J.Perlow, R.S.Preston and D.H.Vincent.
Phys. Rev. Letters, Vol. 4, No. 1, 28-9 (Jan. 1, 1960).

Mössbauer resonant absorption of the 14 keV γ-ray from the first excited state of Fe^{57} was measured at room temperature and at liquid nitrogen temperature using combinations of sources and absorbers either in the metallic form or in the form of thin layers of $FeSO_4.7H_2O$. The results show that the Mössbauer absorption is greatest for a metal foil and metal absorber, but that appreciable absorption also occurs using the non-metallic samples, and that this is greatly enchanced at low temperatures. For a metallic source and absorber at room temperature the transmission of the absorber was measured as a function of source velocity. Uniform source velocities as low as 10 microns/sec were obtained by mounting it on the carriage of a lathe. The transmission dips were about twice the natural line-width (4.5×10^{-9} eV) and allowed an area variation with foil thickness characteristic of a "thick" absorber. An estimate of 0.6 was obtained for the fraction of nuclei emitting or absorbing without recoil at room temperature, and the absorption cross-section at resonance was found to be approximately 1.4×10^6 barns.
R.E.Meads

349 QUANTUM MECHANICAL CALCULATION OF MÖSSBAUER TRANSMISSION. S.M.Harris.
Phys. Rev. (USA), Vol. 124, No. 4, 1178-85 (Nov. 15, 1961).

A quantum-mechanical calculation of the time-dependent Mossbauer transmission is performed neglecting solid-state effects. The source considered consists of nuclei which decay via a two-phonon cascade, the second of which is emitted without recoil and is subject to resonant absorption by a foil whose resonance may be shifted due to a small relative velocity between source and absorber. The transmission is obtained when the transmitted recoilless photon is measured in coincidence with the first photon of the cascade. The results is in agreement with that obtained by considering the absorber as a classical dielectric slab capable of absorption and dispersion. The initial condition is investigated in detail by considering the full cascade. In this manner one sees that the usual simple assumption, that the nucleus is in the first excited state immediately after the emission of the first photon, gives the correct boundary condition.

539.14 : 530.12

7469 MEASUREMENT OF THE RED SHIFT IN AN ACCELERATED SYSTEM USING THE MÖSSBAUER EFFECT IN Fe⁵⁷.

H.J.Hay, J.P.Schiffer, T.E.Cranshaw and P.A.Egelstaff.

Phys. Rev. Letters, Vol. 4, No. 4, 165-6 (Feb. 15, 1960).

The Co⁵⁷ source used in this experiment was plated on to a 0.8 cm diameter iron cylinder which was rotated at speeds up to 500 c/s. The expected fractional shift in the energy was $2.44 \times 10^{-20} \omega^2$, which could be observed at angular velocities down to about 50 c/s. The agreement with the expected shift is good throughout the range of velocities.   E.J.Squires

5927 CAPTURE OF SLOW NEUTRONS BY NUCLEI BOUND IN CRYSTALS.

H.E.Jackson, L.M.Bollinger and R.E.Coté.

Phys. Rev. Letters (USA), Vol. 6, No. 4, 187-9 (Feb. 15, 1961).

The neutron analogue of the Mössbauer effect is investigated.

Experimental determinations were made of the absorption of slow neutrons by uranium metal at room and at helium temperature and by U₃O₈ at room and at nitrogen temperatures. It is claimed that the results agree with theory assuming a Debye model for a solid in the case of uranium, but not in the case of U₃O₈.

CA 6799 (1962)

The Moessbauer effect and its meaning. Vas. Kannelakopoulos (Kernforschungszentrum, Karlsruhe, Ger.). Chim. Chronika (Athens, Greece) 27, 37-9 (1962). A review.   Criton S. Inglessis

539.14

13130 THE MÖSSBAUER RADIATION.

W.E.Kock.

Science, Vol. 131, 1588-90 (May 27, 1960).

Survey article.

600 THE MÖSSBAUER EFFECT. A CONFERENCE REPORT.

D.S.Lieberman and E.Ulscher.

Phys. Today (USA), Vol. 13, No. 11, 20-2 (Nov., 1960).

The conference was held at the University of Illinois on 5-6 June, 1960. Over 80 physicists attended from 9 countries. They reported on their most recent, unpublished experiments and discussed ideas for future research in the field of recoilless gamma-ray absorption.

599 THE MÖSSBAUER EFFECT.

H.Lustig.

Amer. J. Phys., Vol. 29, No. 1, 1-18 (Jan., 1961).

Reviews for nonspecialists the recent discovery and several important applications of recoilless gamma-ray fluorescence. The importance of the fluorescence technique and its limitations, before Mössbauer's discovery, are discussed. Mössbauer's pioneering experiments are briefly described and Lipkin's simple theoretical explanation of recoilless gamma-ray emission is presented. From among the large number of recent experiments which make use of the Mössbauer effect, two groups are selected for discussion. The first is concerned with the discovery of nuclear and magnetic properties of Fe⁵⁷; the other, with a test of the principle of equivalence in general relativity, by a measurement of the gravitational shift in the frequency of radiation.

539.14

15519 THE INFLUENCE OF A MAGNETIC FIELD ON THE RESONANCE ABSORPTION OF γ-RAYS.

V.A.Lyubimov and A.I.Alikhanov.

Zh. eksper. teor. Fiz., Vol. 38, No. 6, 1912-14 (June, 1960).

In Russian.

The Mössbauer effect was used to study the Zeeman splitting of the 23.8 keV γ-transition in Sn¹¹⁹ᵃ. The magnetic moment of the excited state, which was found to depend weakly on the value adopted for the Debye temperature for white tin, was calculated to be $-(1.1 \pm 0.1)$ times the ground state magnetic moment.

E.A.Sanderson

539.161

9040. NUCLEAR RESONANCE FLUORESCENCE IN Ir¹⁹¹ FOR GAMMA RAYS. R.M.Mössbauer.

Z. Phys., Vol. 151, No. 2, 124-43 (1958). In German.

The effective cross-section for resonance absorption of 129 keV γ-rays from the decay of Os¹⁹¹ was measured as a function of the temperature of source and absorber in the range 90-370°K. The lifetime of the 129 keV levels in Ir¹⁹¹ is $(3.5^{+1.2}_{-0.8}) \times 10^{-10}$ sec. For low temperatures the cross-section shows a strong dependence on crystal binding and the theory of Lamb (Abstr. 1374/1939) for neutron absorption is adapted to the present case.   J.M.Rough

539.14 : 539.2

9525 NUCLEAR RESONANCE ABSORPTION OF NON-DOPPLER-BROADENED GAMMA RAYS IN Re¹⁸⁷.

R.L.Mössbauer and W.H.Wiedemann.

Z. Phys., Vol. 159, No. 1, 33-48 (1960). In German.

The absorption was observed in Re¹⁸⁷ bound in a crystal lattice. At 20°K, a small fraction of the gamma-quanta of the 134 keV transition to the ground state is emitted with essentially no energy lost to recoil, the recoil momentum being taken up by the entire crystal, not by the individual nucleus. Nuclei of Re¹⁸⁷ similarly bound in a crystal lattice were irradiated with such gamma-rays emitted without loss of energy, resulting in an observable resonance absorption. Using a relative velocity of the order of 10 cm/sec, the line emitted with the natural line-width was shifted away from the absorption line, resulting in the destruction of the resonance phenomena. Analysis of the variation in transmission as a function of the Doppler shift of the emitted gamma-ray yields a value of $\tau = (1.5 \pm 0.2) \times 10^{-11}$ sec for the lifetime of the 134 keV excited state in Re¹⁸⁷.

CA 13356 (1962)

Moessbauer effect in Fe⁵⁷. Seymour Margulies (Univ. of Illinois, Urbana). U.S. Dept. Com., Office Tech. Serv., AD 264,723, 112 pp. (1961). A series of Moessbauer resonance lines was observed by using a Co⁵⁷ source coplated with stable Fe⁵⁶. Six Zeeman components resulted from the hyperfine splitting of the 14.4-k.e.v. transition of Fe⁵⁷. The spectra were measured by means of Type 310 stainless steel and K₄Fe(CN)₆ absorbers. The transmitted line is approx. a Lorentzian curve with width which increases with increasing source and absorber thickness. The characteristics of the transmitted line depend on the spectral shape. Cases with unsplit source and absorber and with split source and split absorber, were studied.   Frank H. F. Cheng

Moessbauer spectra of some iron complexes. L. M. Epstein (Westinghouse Elec. Corp., East Pittsburgh, Pa.). J. Chem. Phys. 36, 2731-7 (1962). Moessbauer spectra were obtained for the following coordination compds.: Fe phthalocyanine, ferrocene, Fe(CO)₅, Fe(III) acetylacetonate, and Fe(II) acetylacetonate dipyridine; for the following complex ion salts Fe(II) trisphenanthroline chloride, Fe(III) EDTA (ethylenediaminetetraacetate) (mono-Na salt), Fe(II) EDTA, hemin, ferricium picrate, Na₂Fe(CN)₅NO, and some Fe(II) and Fe(III) cyanides. The isomer shift (relative to stainless steel) for Fe(II) has the value expected for an inorg. ion only for Fe(II) EDTA. In the other complexes the shifts were about 0.4 mm./sec., except ferrocyanide, which was near zero. For Fe(III) only hemin and ferricyanide had unusually small isomer shifts. The large neg. isomer shift in Na₂Fe(CN)₅NO suggested Fe(IV). Except for ferrocyanide, quadrupole splittings occurred in Fe of valence 0, II, and IV, and were observed for both spin-paired and spin-unpaired complexes. Splittings varied widely but did not exceed those for inorg. Fe(II) salts. Na₄Fe(CN)₆ showed an unexpected quadrupole splitting. Other Fe(III) complexes gave broad and unsym. spectra.   Henry Leidheiser, Jr.

9

POSSIBLE PARITY AND TIME-REVERSAL EXPERIMENTS USING THE MÖSSBAUER EFFECT.
8635

M.Morita.
Phys. Rev. (USA), Vol. 122, No. 5, 1525-6 (June 1, 1961).

In the successive transition of the beta and gamma decays, the excited and ground states of the daughter nucleus are effectively polarized when the satellites of the Mössbauer effect are separately observed. Using this nuclear polarization, various experiments are proposed to detect parity nonconservation and time-reversal invariance in beta decay. These experiments involve the measurement of the coincidence counting rate of beta rays and satellites of the Mössbauer effect. The resulting improvement in accuracy will make possible, for example, the precision measurement of the asymmetry of beta-ray angular distributions.

5022. Nuclear Resonance Absorption of Gamma Rays IN Ir^{191}. R. L. Mössbauer. Naturwissenschaften Vol. 45, No. 12, 538-9 (1958). In German. The 129keV transition in Ir^{191} is excited, using a centrifuge to compensate for the loss of energy of the γ-ray in the recoil. The width of the line is found to be 6.5 x 10^{-6}eV.

G. E. Brown

539.14
1368 NUCLEAR RESONANCE ABSORPTION OF γ-RAYS IN Ir^{191}. R.L.Mössbauer.
Z.Naturforsch., Vol. 14a, No. 3, 211-16 (March, 1959). In German.

Discusses the appearance of strong spectral lines in the emission and absorption of soft γ-radiation by nuclei at low temperatures. The lines appear to be the consequence of a partial sharing of the γ-recoil momentum by the crystal lattice as well as by the individual nuclei. The superposition of emission and absorption lines produces a strong resonance fluorescence effect; this is suppressed by a "centrifuge" method whereby the emission and absorption lines are shifted relative to each other. The first series of measurements employing this method give a lifetime $\tau = (1.4 \pm {}^{0.2}_{0.1}) \times 10^{-10}$ secs for the 129 KeV level in Ir^{191}.

S.J.St-Lorant

539.14
11312 NUCLEAR RESONANCE FLUORESCENCE IN Au^{197}.
D.Nagle, P.P.Craig, J.G.Dash and R.R.Reiswig.
Phys. Rev. Letters, Vol. 4, No. 5, 237-9 (March 1, 1960).

The Mössbauer effect was investigated for the case of the 77 keV γ-ray line of Au^{197} using as sources, either the β^- parent Pt^{197} or the electron capture parent Hg^{197}, the sources being maintained at a temperature of 4°K. The shape of the resonance absorption curve was obtained by measuring the transmission of an Au absorber as a function of the relative velocity of a Pt^{197} source. This gave a velocity half-width of 3.5 ± 0.5 mm/sec. Measurements using absorbers of different thickness yielded values of the effective temperatures Φ for the Au and Pt lattices of 54° and 127°K respectively. The results disagree with the predictions of the simplified Debye model of phonon excitation in solids which would give $\Phi = 2/3 \theta$, θ being the Debye characteristic temperature. Values of $\theta = 165°$K for Au and 233°K for Pt were assumed in this calculation. The mean lifetime of the 77 keV state was found from these results to be 0.62 ± 0.15 mμsec. The effect of placing the source and absorber atoms in different crystal lattices was also investigated. It was found, for example, that placing the emitting atoms in a lattice which is predominantly Au resulted in strong enhancement of the resonance effect.

R.E.Meads

539.14
13126 ULTRA-HIGH RESOLUTION γ-RAY RESONANCE IN ZINC-67. D.E.Nagle, P.P.Craig and W.E.Keller.
Nature (London), Vol. 186, 707-8 (May 28, 1960).

Mössbauer resonance absorption was observed of the 93 keV γ-ray from the 9.4 μsec first excited state of Zn^{67}. The ratio of natural line-width to γ-ray energy is in this case 1/10^{15} and is 10^3 narrower than in Fe^{57}. An annealed source of Ga^{67} produced by deuteron irradiation of zinc oxide was mounted close to a zinc oxide absorber in a liquid helium cryostat. Observations were made of the magnetic field required to be applied to the absorber to destroy the resonance condition by nuclear Zeeman effect. With an applied field of 500G the absorber transmission of the 93 keV γ-ray increased by (0 240 ± 0.025)%. No resonance absorption effect was observed at room temperature or at low temperature using an unannealed zinc oxide—alumina absorber, in which it might be expected that the active Ga atoms would be displaced from their proper lattice positions.

R.E.Meads

5830 MÖSSBAUER EFFECT WITH Ni^{61}.
F.E.Obenshain and H.H.F.Wegener.
Phys. Rev. (USA), Vol. 121, No. 5, 1344-9 (March 1, 1961).

The Mössbauer effect was observed in Ni^{61}. The Ni^{61m} was obtained by

$$Ni^{64}(p,\alpha)Co^{61} \xrightarrow{\beta^-(99 \text{ m in})} Ni^{61m},$$
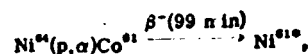
giving a nickel Mössbauer nucleus in a Ni^{64} host lattice. The magnitude of the effect at T = 80°K is about 4% for a 400 n g cm^{-2} absorber foil (natural nickel). From the thickness dependence the authors obtain $f_{source} = f_{abs} = (9 \pm 1)$% for the Debye—Waller factor at T = 80°K. The temperature dependence yields a Debye temperature varying between 413° and 437°. The velocity dependence has a half-width of 1.65 mm sec^{-1}. The spectrum deviates from the Lorentz shape expected for a single line. A recent electronic determination of the lifetime of this 71 keV state indicates a natural half-width of 0.37 mm sec^{-1}. The increased half-width and shape of the spectrum observed in this experiment may be understood in terms of a magnetic hyperfine splitting. The moment of the ground state is known. The internal field H and the magnetic moment μ_e of the first excited state are unknown. An analysis of the data gives a connection between the two quantities, μ_e(H).

THE THEORY OF THE MÖSSBAUER EFFECT.
13631 J.Petzold.
SB heidelberg. Akad. Wiss. (math. nat. Kl.) (Germany), 1961, No. 5, 45 pp. In German.

A review article concerned with the systematic presentation of the theory underlying the Mössbauer effect.

S.J.St-Lorant

539.14 : 539.2
MÖSSBAUER EFFECT IN FERROCYANIDE.
9524 S.L.Ruby, L.M.Epstein and K.H.Sun.
Rev. sci. Instrum., Vol. 31, No. 5, 580-1 (May, 1960).

The change in γ-ray transmission from a Co^{57} source with velocity was measured for an Fe absorber at room temperature, and a sodium ferrocyanide absorber at 80°K and at room temperature. A ferrocyanide source is expected to emit about 40% of 14.4 keV γ-rays without energy change, compared with 60% for soft iron.

J.Franks

6794. On the possibility of a new phase - determining method applying the Mössbauer effect. R. S. Raghaven.
Proc. Indian Acad. Sci. A, Vol. 53, No 6, 265-72 (June, 1961)
When soft y-rays are emitted without recoil, the radiation emitted has a considerable fraction contained within the natural line-width. This part of the radiation is expected to be partially coherent with the incident y-rays and so with the Rayleigh scattered component. Under these conditions the total scattering amplitude will be a sum of the Rayleigh and resonance amplitudes. This coherent addition leads to an enhancement of the intensities of Bragg reflections from the crystal. Since the total amplitude is complex, the intensities of inverse reflections will be unequal. It is suggested that this possibility be utilized, as in the similar case of anamalous dispersion of x-rays, for determining the phase constants and also the absolute configuration of crystals. Practical limitations are discussed.

9998 THE MÖSSBAUER EFFECT.
F.L.Shapiro.
Uspekhi fiz. Nauk (USSR, Vol. 72, No. 4, 685-96 (Dec., 1960).
In Russian.
Gives a survey of theoretical and experimental work. Begins with a classical discussion of the effect. Further discusses the influence of the quadratic Doppler effect, coherent effects, treats the case of an impurity, and the case of gaseous and liquid sources. Discusses experiments on Sn^{119} and Zn^{97} and gives comments on further possibilities. Provides a summary of all the Russian work in this field. [English translation in: Soviet Physics—Uspekhi (USA), Vol. 3, No. 6, 881-7 (May-June, 1961)]. F.Herbut

2697.Thermal broadening of the Mössbauer line and of narrow-line electronic spectra in solids. R. H. Silsbee.
Phys. Rev. (USA), Vol. 128, No. 4 1726-33 (Nov. 15, 1962)
The dependence of the lattic vibration Hamiltonian upon the excitation state of an electron or nucleus is examined as a possible source of thermal broadening of narrow-line electronic spectra or Mössbauer spectra in solids. A simple model is proposed to illustrate this mechanism and calculated techniques described to determine the line width appropriate to that model. Application to the Mössbauer problem shows the absence of any observable thermal broadening except in the case of localized modes. The mechanism is consistent with the observed thermal broadening of the narrow line of ruby, but this specific problem appears to be too complex to permit a detailed test of the theory

17882 BROADENING OF THE MÖSSBAUER LINE.
H.S.Snyder and G.C.Wick.
Phys. Rev., Vol. 120, No. 1, 128-9 (Oct. 1, 1960).
The thermal excitation of the solid which leads to a temperature-dependent shift of the Mössbauer line could conceivably cause a broadening of this line. Here it is shown, by a quantum-mechanical treatment, that for a perfect crystalline solid such a broadening does not occur.

15517 THE MÖSSBAUER EFFECT IN PYRITES AND MARCASITE. I.Solomon.
C.R. Acad. Sci. (Paris), Vol. 250, No. 23, 3828-30 (June 8, 1960).
In French.
The observations in two different structures of FeS_2 allowed a determination of the quadrupolar interaction between the excited state of Fe^{57} ($I' = \frac{3}{2}$) and the crystalline field. The centre of the spectrum is displaced towards positive energies by an amount $\epsilon = +3.8 \pm 0.2$ Mc/s.
D.J.Oliver

P.A.
Feb. 1963
Mossbauer scattering of low energy gamma-rays. B. S. Sood.
Indian J. Phys. Vol. 36, No. 8, 419-21 (Aug. 1962)
Mössbauer scattering cross-section of 14.4keV gamma rays in Fe^{57} is found to be 142 ± 30 barns; this agrees with theory if the levels involved in the scattering are assumed to be split. This type of scattering may be used to investigate problems regarding the coherence between resonance and Rayleigh scattering processes.

THE MÖSSBAUER EFFECT: A TOOL FOR SCIENCE.
13630 G.K.Wertheim.
Nucleonics (USA), Vol. 19, No. 1, 52-7 (Jan., 1961).
A review of the effect in which gamma emission and absorption takes place in a solid with the whole crystal, rather than the individual atom, absorbing the recoil energy. The photons then have an energy almost equal to the nuclear transition energy. The fractional uncertainty in energy depends only on the lifetime of the excited nuclear state and may be as low as one part in 10^{13}. The experimental observation of the effect, its use in nuclear spectroscopy (including measurement of hyperfine structure), measurement of gravitational shift and possible future measurements in solid-state physics are discussed.
R.D.Smith

994 STUDIES OF THE INTERNAL FIELDS ACTING ON NUCLEI IN FERRIMAGNETIC AND PARAMAGNETIC SOLIDS, USING RECOIL-FREE RESONANCE ABSORPTION (MÖSSBAUER EFFECT). R.Bauminger, S.G.Cohen, A.Marinov and S.Ofer.
J. Phys. Soc. Japan, Vol.17, Suppl. B-1, 123-4 (March, 1962).

"Magnetism and Crystallography" Conference, Kyoto, 1961. I. Magnetism (see Abstr.21284 of 1962). Recoil-free gamma-ray absorption spectra were observed in ferrimagnetic and paramagnetic solids containing nuclei of Fe^{57} and Dy^{161}, using radioactive sources of Co^{57} and Tb^{161}. The hyperfine Zeeman splittings in ferrimagnetic materials permit a determination of the effective magnetic field (H_{eff} at the nuclei. H_{eff} at Fe^{57} nuclei in yttrium iron garnet, dysprosium iron garnet and in some spinel ferrites were measured at 300° and 85°K. Measurements on Fe_3O_4 confirm Verwey's hypothesis of a fast exchange between ferrous and ferric ions in the octahedral sites above the transition temperature. H_{eff} at Dy^{161} in dysprosium iron garnet was found to be $3 \cdot 5 \cdot 10^6$ Oe at 85°K and $7 \cdot 5 \cdot 10^5$ Oe at 300°K and was proportional to the Dy sublattice spontaneous magnetization. A large temperature-dependent quadrupole interaction in DIG was observed, which is ascribed to an effective electric field gradient at the Dy nuclei produced by the partially aligned orbitals of the 4f electrons, and thus correlated with the spontaneous magnetization.

LOCAL MAGNETIC FIELDS IN Fe—Al ALLOYS.
P.A.Flinn and S.L.Ruby.
Phys. Rev. USA, Vol. 124, No. 1, 34-6 (Oct. 1, 1961).
In apparent contrast with recent results on Fe—Co and Fe—V alloys, the Mössbauer spectra in ferromagnetic Fe—Al alloys are both blurred and contracted as the fraction of aluminium is increased. This phenomenon is consistent with a model where the inner field at a given iron atom depends strongly on number of aluminium nearest neighbours.

350 ANISOTROPY OF γ-RADIATION IN THE MOSSBAUER EFFECT. A.Gel'berg.
Zh. eksper. teor. Fiz. (USSR), Vol. 41, No. 1(7), 115-17 (July, 1961). In Russian.
Calculated for the case when the source is in a magnetic field (external magnetic field or field of ferromagnetic domains). [English translation in: Soviet Physics—JETP (USA)].

22712 ANISOTROPY OF γ-RADIATION IN THE MOSSBAUER EFFECT. A.Gel'berg.
Zh. eksper. teor. Fiz. (USSR), Vol. 41, No. 1(7), 115-17 (July, 1961). In Russian.   English translation in: Soviet Physics—JETP (USA), Vol. 14, No. 1, 86-7 (Jan., 1962).
For abstract see Abstr. 350 of 1962.

539.2 : 538.2 : 539.14
11827 DIRECTION OF THE EFFECTIVE MAGNETIC FIELD AT THE NUCLEUS IN FERROMAGNETIC IRON.
S.S.Hanna, J.Heberle, G.J.Perlow, R.S.Preston and D.H.Vincent.
Phys. Rev. Letters, Vol. 4, No. 10, 513-15 (May 15, 1960).

By observing the change in the hyperfine splitting of the nuclear energy levels, using the Mössbauer effect, the effective magnetic field at the iron nucleus is found to be antiparallel to the direction of magnetization.   E.A.Sanderson

996 INTERACTION BETWEEN Fe^{57} AND ITS CRYSTALLINE SURROUNDINGS.
L.G.Lang, S.DeBenedetti and R.I.Ingalls.
J. Phys. Soc. Japan, Vol.17, Suppl.B-I, 131-3 (March, 1962).
"Magnetism and Crystallography" Conference, Kyoto, 1961. I. Magnetism (see Abstr.21284 of 1962). The quadrupole splittings of the Mössbauer absorption patterns of Fe^{57} in $FeSO_4 \cdot 7H_2O$, $FeCl_2 \cdot 4H_2O$, and $Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$ were measured as a function of temperature. Low temperature limiting values of the splittings were found to be $0 \cdot 350$ cm sec^{-1}, $0 \cdot 315$ cm sec^{-1}, and and $0 \cdot 277$ cm sec^{-1} (all $\pm 0 \cdot 005$ cm sec^{-1}) respectively. The temperature dependence is interpreted in terms of the temperature-dependent occupation probabilities of the triplet states of the ferrous d-electron. Characteristic temperatures of 800°, 1000°, and 380° respectively are assigned. A computation indicates that the anti-shielding factor for the field gradient caused by the ferrous d electron is $\gamma = 0 \cdot 42$. The magnitude of the quadrupole moment of the excited state of Fe^{57} is estimated to be $0 \cdot 18$ barn.

995 THE MÖSSBAUER EFFECT IN SOME IRON COMPOUNDS. K.Ôno, Y.Ishikawa, A.Ito and E.Hirahara.
J. Phys. Soc. Japan, Vol.17, Suppl.17, 125-9 (March, 1962).
"Magnetism and Crystallography" Conference, Kyoto, 1961. I. Magnetism (see Abstr.21284 of 1962). Magnetic properties of Fe_3O_4, αFe_2O_3, $FeS_{1.00}$, $FeS_{1.01}$ and Fe_3Al were investigated with the method of the Mössbauer effect. The results obtained in this work are listed in tabular form.

16918 A MÖSSBAUER STUDY OF THE INTERNAL FIELD AT Fe^{57} IN γ-Fe_2O_3. K.Ôno and A.Ito. ●
J. Phys. Soc. Japan, Vol. 17, No. 6. 1012-17 (June, 1962).
Mössbauer absorption by Fe^{57} in α-Fe_2O_3 was measured as a function of temperature from 100°K to 1050°K. In the hyperfine spectra, a steep change of the energy shift ϵ due to quadrupole interaction was found at about 260°K. The ratio of ϵ at 100°K to that at 300°K is -2.0 ± 0.4. This value corresponds to the ratio of $(3 \cos^2 \theta - 1)$ below and above the transition temperature, if it is assumed that the direction of the principal axis of the electric field gradient at the iron nucleus is parallel to the c-axis. A careful observation of the shape of the absorption line near the transition temperature showed that each line consisted of a doublet. This fact reveals that the transition temperature of α-Fe_2O_3 used in the present experiment varied locally from 220°K to 270°K. The value of e^2qQ obtained at about 260°K is (+ 0.084 $\pm$ 0.008) cm/sec = (+ 9.7 $\pm$ 0.09) Mc/sec. Although there were fairly large errors in the values obtained for e^2qQ, the field gradient seemed to increase slowly with temperature from 100°K to 700°K. The abrupt increase of the field gradient was found near the Néel temperature. The observed temperature dependence of the internal magnetic field was fairly consistent with the molecular field theory for S = 5/2.

997 MÖSSBAUER STUDY OF $FeTiO_3$ AND ITS SOLID SOLUTIONS WITH αFe_2O_3. G.Shirane and S.L.Ruby.
J. Phys. Soc. Japan, Vol.17, Suppl. B-I, 133-5 (March, 1962).
"Magnetism and Crystallography" Conference, Kyoto, 1961. I. Magnetism (see Abstr.21284 of 1962). The solid solutions (1-x) $FeTiO_3$-xFe_2O_3 exhibit strong ferromagnetic moments for the compositions x 0.6, where the Fe and Ti ions are ordered in the alternate (111) layers. The anomaly revealed by the Mössbauer measurements is that the ferrimagnetic phase consists of ferrimagnetic clusters surrounded by paramagnetic media. The size of these clusters decreases with increasing temperature of increasing local concentration of Ti. The isomer shift $FeTiO_3$ is $1 \cdot 2$ mm sec^{-1} at room temperature as expected for Fe^{2+}. At 20°K, the hyperfine field was found to be 70 kOe, considerably smaller than the expected value for Fe^{2+}.

6248 MEASUREMENT, BY MEANS OF THE MÖSSBAUER EFFECT, OF LOCAL FIELDS IN VARIOUS COMPOUNDS OF IRON. I.Solomon.
C.R.Acad. Sci. (France), Vol. 251, No. 23, 2675-7 (Dec. 5, 1960). In French.
The Mössbauer effect was observed in: (a) substances where the local field is zero; (b) substances where the instantaneous value of the local field is non-zero but due to the rapid fluctuations the average effect of the field is zero; (c) in a garnet where the measured values of the local field at two sites were found to be 390 ± 7 kOe and 490 ± 7 kOe with relative intensities 3 and 2, respectively.   E.A.Sanderson

3133. A study of the magnetic properties of the $FeTiO_3$-Fe_2O_3 system by neutron diffraction and the Mössbauer effect. G. Shirane, D. E. Cox, W. J. Takei and S. L Ruby. J. Phys. Soc. Japan. Vol. 17, No. 10, 1598-1611. (Oct., 1962)

The solid solutions $(1-x)FeTiO_3 -x Fe_2O_3$ exhibit strong ferrimagneric moments in the composition range $0.1 < x < 0.6$. In this region cation ordering is thought to occur such that the Fe^{2+} and Ti^{4+} ions occupy alternate (111) layers, thus forming sublattices $A[x Fe^{3+}, (1-y)Fe^{2+}]$ and $B[x Fe^3, (1-y)Ti^4]$. A neutron diffraction study shows that at least 95% of the Ti ions are located on the B layer but that they are not ordered within the layer. The temperature dependence of the magnetic intensities of a number of ferrimagnetic phases reveals that both sublattice moments, at zero magnetic field, fall considerable short of the theoretical values. In addition, Mössbauer patterns indicate that paramagnetic behaviour persists over a rather wide temperature range below the Néel temperature of solid solutions in which $x = 0.21$ and $x = 0.33$. These results are interpreted as a consequence of inhomogeneity in the magnetic structure, due to competing interactions as a result of the Ti ions being disordered within the layer.

The centre shift and quadrupole splitting for $FeTiO_3$ were measured over a wide temperature range. By using these results, the Mössbauer absorption by solid solutions above their Néel points can be interpreted as a superposition of the absorption peaks of Fe^{2+} and Fe^{3+}.

539.2 : 538.2 : 539.14

11826 MEASUREMENT OF LOCAL FIELDS AT IMPURITY Fe^{57} ATOMS USING THE MÖSSBAUER EFFECT.
G.K.Wertheim.
Phys. Rev. Letters, Vol. 4, No. 8, 403-5 (April 15, 1960).

Local magnetic fields at Fe^{57} nuclei in Fe, Co, Ni and n-type silicon are investigated, using these as sources. Stainless steel and diamagnetic potassium ferrocyanide, which exhibit unsplit absorption lines, are used as absorbers. Values of the local magnetic fields, in oersteds, are found to be 3.3×10^5, 3.1×10^5, and 2.6×10^5 in Fe, Co, and Ni, respectively, and 3×10^4 for an iron atom occupying a site characteristic of a cobalt atom in silicon.

E.A.Sanderson

1197 HYPERFINE STRUCTURE OF Fe^{57} IN PARAMAGNETIC AND ANTIFERROMAGNETIC FeF_2 FROM THE MÖSSBAUER EFFECT. G.K.Wertheim.
Phys. Rev. (USA), Vol. 121, No. 1, 63-6 (Jan. 1, 1961).

Measurements of the gamma-ray resonant absorption in oriented slabs of FeF_2 were used to determine the magnitude and direction of the magnetic field at the iron nucleus in the antiferromagnetic state (3.40×10^5 Oe at $0°$ K) and the quadrupole splitting in the paramagnetic state (31.2 Mc/s) of this material. The observed electric and magnetic h.f.s. in the antiferromagnetic state is interpretable in terms of an asymmetric electric field gradient tensor with its major axis perpendicular to the c axis, an asymmetry parameter of 0.33, and a quadrupole splitting of 30.3 Mc/s at $45°$K.

6249 MÖSSBAUER EFFECT: APPLICATIONS TO MAGNETISM. G.K.Wertheim.
J. appl. Phys. (USA), Suppl. to Vol. 32, No. 3, 110S-117S (March, 1961).

The Mössbauer effect, the resonant absorption of nuclear gamma rays in solids, may be used to obtain the hyperfine structure of Fe^{57} in magnetic materials. Experiments are performed by observing the absorption by stable Fe^{57} of the 14.4 keV gamma ray coming from a source which contains radioactive Fe^{57} produced by the decay of Co^{57}. The experiments are not limited to naturally iron-bearing materials; other substances can be studied provided only that small amounts of cobalt can be introduced into lattice sites of interest. The magnetic moments of the ground and first excited states of Fe^{57} are known and make possible direct determination of the field at the iron nucleus once the hyperfine structure has been measured. The magnetic field at iron nuclei has been determined in the ferromagnetic transition metals (Fe 3.42×10^5 Oe, Co 3.12×10^5 Oe, Ni 2.80×10^5 Oe at $0°$ K) but no hyperfine structure has been observed down to $4°$ K in the antiferromagnetic transition metals, Mn and Cr. In the case of YFe-garnet the fields at the iron atoms in the two types of sites have been obtained (tetrahedral 3.9×10^5 Oe, octahedral 4.7×10^5 Oe). The most complete analysis so far has been made in FeF_2 where the magnetic field in the antiferromagnetic state ($H_{T=0} = 3.40 \times 10^5$ Oe) and the quadrupole splitting in the paramagnetic state (31.2 Mc/s) have been obtained. Other materials under investigation are the iron oxides and some ferrites, where, for trivalent iron, fields in the vicinity of 5.0×10^5 Oe have generally been found.

The origin of the effective magnetic fields at the nuclei of magnetic materials which have been determined by Mössbauer, nuclear magnetic resonance, electron paramagnetic resonance, specific heat, and nuclear polarization methods is investigated theoretically by means of the exchange polarization mechanism. Exchange-polarized iron series Hartree—Fock calculations are carried out for (a) free ions and neutral atoms, (b) ions in a free crystalline field (as in a salt), and (c) spin densities and configurations which conform with energy band and neutron magnetic scattering observations for the ferromagnetic metals. The effective field data for metals, ferrites, rare-earth garnets, and salts are then discussed and it is shown that the dominant contribution to the effective field (in almost every case) arises from the (exchange) polarization of the core electrons by the spin density of the unpaired outer electrons. For the transition metals, the role of the conduction electrons is analysed including some new contributions not previously considered. The data for ions like Fe^{3+} and Mn^{2+} are understood mainly on the basis of the core polarization term; such factors as covalent bonding, charge transfer, crystal field effects (such as distortions from cubic symmetry) must also be included. For ions like Fe^{2+} and Co^{2+} the (large) field due to unquenched orbital angular momentum must also be considered and several cases in which the orbital field dominates are discussed. The exchange polarization method and the accuracy of the analytic spin-polarized Hartree—Fock functions are discussed with regard to the sensitivity of the internal field to orbital descriptions, the effect of crystalline environments, and to expansion and contraction of the spin density. Each factor is investigated in detail by means of accurate exchange-polarized calculations. In conjunction with these studies a restricted Hartree—Fock calculation for Mn^{2+} was carried out (and is reported as an Appendix) which is more accurate than existing calculations and indicates the accuracy of earlier analytic Hartree—Fock calculations.